Lithonia Lighting and the
U.S. Department of Energy's
Rebuild America present

The Basics of Efficient Lighting

U.S. Dept. of Energy

Rebuild America S.M.

"Rebuild America helps communities become stronger, cleaner, and more environmentally and economically sound through smarter energy use. The program starts with building renovation-and expands from there-to include renewable energy, efficient new building design, energy education, and other innovative energy and resource conservation measures. Ultimately, communities benefit from revitalized neighborhoods and main streets, improved school facilities, better low-income housing, and the positive economic impact brought by keeping local dollars at home. Rebuild America and its Business Partners work together to make the connection between the energy efficiency needs of the community and market-based solutions of industry."

"Lithonia Lighting, as a charter Business Partner of Rebuild America, has produced this efficient lighting guide as a service to communities and building decisionmakers around the country."

January 2000

The Basics of Efficient Lighting
Energy… Productivity… Aesthetics

Contents

Introduction

Lighting design is a creative process that generates solutions which provide for the safe, productive and enjoyable use of a space. Proper lighting design addresses not only the quantity of light needed but also the quality of that light. The light we introduce into a space shapes our environment both visually and emotionally. Lighting design must be concerned with a wide range of issues including energy efficiency and productive occupants.

This pamphlet is an introduction into that process. It attempts to acquaint you with some of the complexities involved in lighting. It assumes that you are a relative novice to both the art and science of lighting but is involved in some project where lighting will play a significant role. It is meant to help you to be involved in the lighting design process in a pro active manner.

Towards that end, this pamphlet is divided into four main sections.

- It first discusses a concept called High Benefit Lighting which lays the conceptual foundation for how one might approach the lighting design process.
- The second section is a glossary of common lighting terms and a generic description of some of the more common types of lighting fixtures to be considered in a typical lighting design. These allow the reader to know the language.
- The next section provides some technical background to some of the more topical issues of lamp technology, ballasts and lighting controls.
- Finally, applications are discussed providing the user with some specific guidelines on lighting design and a list of issues to discuss with the lighting contractor. This last section also includes a bibliography of some useful, lighting-related web sites.

Section 1 - A Conceptual Foundation

High Benefit Lighting

What is high benefit lighting?

It's remembering why we put lighting fixtures in a space in the first place. It is NOT simply to provide lighting. Instead, we install light fixtures to provide **the right amount** of lighting and in a way that occupants will find pleasing and conducive to performing their assigned tasks. Put another way, high benefit lighting is lighting that optimizes performance of the tasks for which illumination is needed, while minimizing the operations, maintenance and energy costs.

The real cost of lighting!

A poorly designed lighting system may save some energy costs but end up losing much more than it saves. Poor lighting can result in higher reject rates, increased absenteeism, slower performance and decreased safety. All lighting should be evaluated over a full range of parameters including the amount of light needed for a task, potential glare, energy costs, color issues, aesthetics, etc.

The real benefit of lighting!

Consider the case of Superior Die Set Corporation in Oak Creek, Wisconsin. There, new lighting not only reduced lighting operating and maintenance costs by 45 percent, saving $2,148 per year, it also improved overall productivity and reduced downtime, saving an additional $42,836 annually. In addition, it lowered the reject rate, reduced absenteeism, and enhanced security; benefits whose bottom-line values could not easily be calculated. The company earned a simple payback on its investment *in less than 24 days*. Not all lighting retrofit projects will yield this level of payback, but when all of the factors are considered, payback periods can be impressive.

What's Involved?

First things first

Before you begin a crusade for better lighting, recognize that *all* parties need to understand the relationship between lighting, the work being performed and the degree to which improved lighting affects the bottom line. In a situation involving 200 workers, and an average cost per worker–including Social Security costs and benefits–of $25,000, a 5 percent productivity increase is worth about $250,000 each year.

Recognize that the dollars associated with lighting are far in excess of the illumination system's annual operation and maintenance cost. Those involved should also recognize the need to gather more information about the specific procedures needed to achieve an optimized system.

By being more conversant about the topic, you should be able to communicate effectively and thereby help the lighting designer develop a better system. Assistance is available from lighting consultants and illuminating engineers, including those who work independently as well as others who may be employed by utilities, manufacturers, electrical contractors, electrical distributors, lighting management companies, and contract cleaning companies.

While in-house personnel may have a comprehensive knowledge of lighting in general and know how to make the overall system more efficient, it takes highly-specialized training and experience to understand the relationship between lighting quality and productivity, reject rate reduction, safety, and so on.

Conduct an audit

The first step toward renovation for high-benefit lighting is conducting an audit. This involves an analysis and evaluation of the existing lighting system, the tasks being performed, and the individuals performing them. This information determines electric illumination needs, the ability of the existing system to meet those needs, opportunities available to improve the existing system by walking through a facility.

An experienced lighting professional often can conduct an audit on a walk-through basis, complemented by a review of utility bills. At the same time, the professional should be able to identify alternative actions that you can take to enhance the existing system.

Query the utility

Many electric utilities offer rebates, low-cost loans, and other incentives to encourage industries to improve the efficiency of their lighting systems. The utilities' goal is to reduce lighting energy consumption and thereby forestall the need to build new generating plants. They also want to reduce the amount of pollutants emitted into the atmosphere.

The nature of the equipment targeted by the utilities helps determine which alternatives will be most cost-effective. Some utilities have third-party provider programs through which an entirely new lighting system can be installed and paid for on a *share-the-savings* basis. These third-party provider programs also may be available independent of utilities.

Build in efficiency

The vast array of new energy-efficient equipment makes incorporation of energy conservation principles simple, for system upgrading or for replacement.

Some lamps produce the same amount of light and consume far less energy while others produce far more light for the same amount of energy. The latter are most effective when the audit indicates that the existing amount of illumination (illuminance) is insufficient.

Luminaires (lighting fixtures) also have an important impact on efficiency. The most significant efficiency factor typically is *coefficient of utilization*. A coefficient of utilization of 0.70 indicates that 70 percent of the raw lumens produced by the lamps in the luminaire are distributed to the workplane.

Theoretically, the higher the coefficient of utilization of the luminaires selected, the fewer luminaires are needed to produce desired illuminance. Thus, a higher coefficient of utilization should reduce capital requirements in addition to ongoing energy and maintenance costs.

High coefficients of utilization are not the only concern however. Another important luminaire rating factor is called *visual comfort probability.* Visual comfort probability indicates the amount of discomfort glare likely to be produced by a given luminaire when the lighting system is composed entirely of that luminaire type.

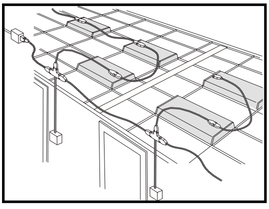
Glare is the sensation you experience when you are temporarily blinded at night by the *high beams* of an oncoming vehicle. Known as *disability glare*, it causes you to avert your eyes. Discomfort glare is more common and caused by a bright source in your field of view. You are not temporarily blinded by it because its lesser severity can be accommodated by tiny muscles that cause your eye to adapt. Over time, however, these muscles can become strained, leading to eyestrain and headaches, absenteeism, and myriad other problems, including lower productivity and higher reject rates.

Likewise, the use of the wrong luminaire in applications that include VDT usage can result in veiling reflections where the intended screen images become difficult to see due to reflected images of the light fixtures in the room. For these reasons, among others, lighting system retrofits that involve renovating luminaires by installing new reflective materials must be looked at with particular care. If that approach is used, it is essential to ensure that the quality of light provided by the renovated fixtures is what's required to support task performance.

The cost of renovation must be examined closely too. In the case of fluorescent luminaires, for example, it is common to recommend not only new reflective surfaces, but new ballasts as well. However, the cost of renovation may be very close to the cost of replacement, making the latter alternative something worth close review.

Build in flexibility

Flexibility often is accomplished through the use of lighting controls, devices almost always called for to boost or maintain efficiency. Dimming controls have the benefit of permitting workers to adjust lighting to meet their particular needs and preferences. They also permit lower lighting levels when workstations are unoccupied or when light is available through windows and skylights.



Flexibility can be accomplished through reliance on flexible branch wiring and movable luminaires such as those indicated in the figure to the left. These luminaires are easily removed, permitting substitution of fixtures when tasks change and relocation of fixtures when the work area layout is modified. Again, being able to put the right kind of light where it is needed and when it is needed can be significant in enhancing overall quality and, thus, overall productivity, safety, and other positive benefits.

Build in good maintenance and sustainability

The impact of good maintenance on overall lighting efficiency and quality cannot be stressed enough. Without maintenance, dirt and dust quickly build up on fixtures and lamp surfaces trapping light, lowering efficiency, changing light distribution, and affecting quality.

Fortunately, many industrial lighting designers assume that inadequate maintenance will be performed and, to compensate, they include additional *compensatory* lighting in the system so that adequate lighting is available. Unfortunately, that approach increases both initial and long-term operations and maintenance costs.

Accordingly, by resorting to high-quality maintenance, it may be possible to eliminate up to 10 percent (or more) of the installed lighting. High-quality maintenance allows lighting users to achieve a system that is far more efficient and actually provides better quality.

For more details on High-Benefit Lighting including a variety of case studies, visit the web site of the National Lighting Bureau (www.nlb.org).

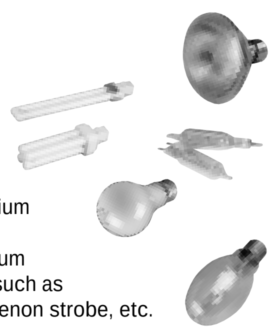
Consider labeling new or retrofitted fixtures with labels to identify the type of lamps, their color temperature and color rendering, the type of ballast and the installation date. This will increase the likelihood that the correct lamps and ballasts be used in the future.

USE ONLY T-8 LAMPS
COLOR: 3500k CRI: 84+
ELECT. RAPID START BALLAST
INSTALLED: 12/99

Consider implementing a group relamp program. Relamping refers to wholesale replacement of lamps at predetermined intervals. A typical strategy is to replace all lamps when they have reached 70-80% of their rated life (the time when 50% of the lamps are still operating). Group relamping reduces maintenance costs associated with individual lamp replacement, schedules replacement to maintain illumination levels and provides an opportunity to clean fixtures.

Section 2 - The Basics

Lighting Nomenclature



LAMP

The term lamp is used to describe a device that creates light. The most common term for this is the light bulb.

Common lamp types include:

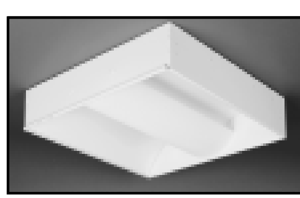
- ❑ Incandescent
- ❑ Halogen (which is a special kind of incandescent)
- ❑ Fluorescent
- ❑ Metal Halide
- ❑ High Pressure Sodium
- ❑ Mercury Vapor
- ❑ Low Pressure Sodium
- ❑ Specialty sources such as neon, carbon arc, xenon strobe, etc.

HIGH INTENSITY DISCHARGE (HID)

This term defines a class of lamps made up of the following lamp types: metal halide, high pressure sodium and mercury vapor.

BALLAST

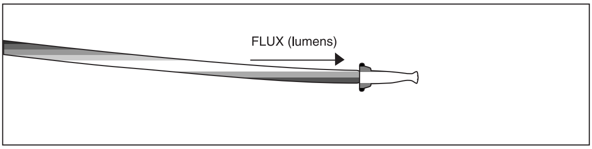
The incandescent lamp is run straight off the electricity coming out of the wall socket. However, other lamp types need to have that electricity controlled in order to start and operate efficiently. A ballast is an electrical device used in fluorescent and HID luminaires to regulate starting and operating characteristics to the lamp. For more details, see the later section entitled: ***Let's Talk Ballasts***.



LUMINAIRE

The luminaire is the entire light fixture including the lamp, ballast (if any) and the housing.

FLUX



Units: lumens

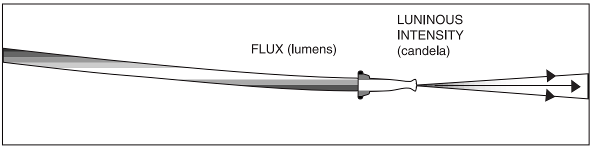
Flux is a measure of how much total light is being emitted, reflected, etc. Its most common use is to quantify how much light a bare lamp is emitting (e.g., a particular fluorescent lamp emits 2,900 lumens while a particular metal halide lamp emits 110,000 lumens). A commonly used analogy is to think of a garden hose being used to water your yard. The amount of water, or number of gallons, being carried by the hose is the equivalent, conceptually, of the flux or number of lumens being emitted by the lamp.

LUMINOUS INTENSITY

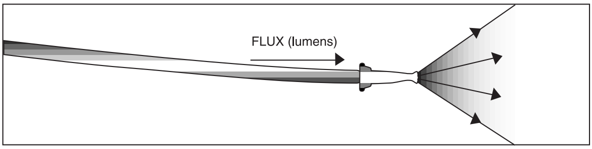
Units: Candelas (candlepower)

This term is used to describe how much light is being emitted in a particular direction. Think of an adjustable bib at the end of our hose. We can set it (as in A below) such that it sends out a concentrated flow of water in one direction while very little water, if any, goes in the other directions. Or we can set it to make a gentle spray over a wide range of directions as in B below. Likewise, the optics in a light fixture (a luminaire) is used to control the direction and the amount light that is to be emitted by the luminaire, with it sending more light in some directions than others. That amount is specified in candelas.

A. Concentrated Intensity



B. Wide-Spread Intensity

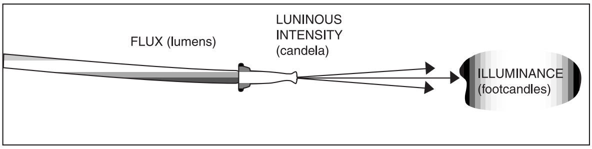


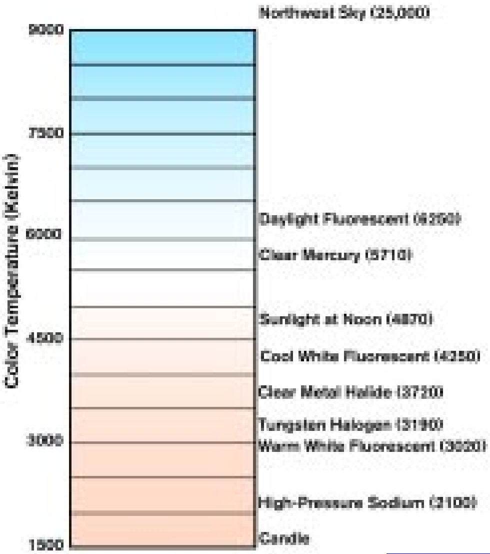
ILLUMINANCE

Units: footcandles (English) or lux (Metric)

Illuminance is a measure of how much light is falling on a surface. If we continue our hose analogy, we might spray 10 gallons of water over an area of 5 square feet. This would give us 2 gallons per square foot. Likewise, if we cover the floor of a 20’ x 20’ room with 40,000 lumens, its illuminance is 100 lumens per square foot, which is 100 footcandles.

1 footcandle = 1 lumen/square foot
1 lux = 1 lumen/square meter
1 footcandle = 10.76 lux





COLOR TEMPERATURE

Color temperature is the term used to specify the color of a lamp. In laymen's terms, it is the temperature a standard piece of metal would have to be to "glow" a certain color. That is, a lamp with a 4100K color temperature would have the same color as a piece of standard metal that has been heated up to that temperature. (K = degrees Kelvin). This chart shows the color temperatures of some standard lighting conditions. The higher the Kelvin temperature, the cooler (bluer) its appearance.

COLOR RENDERING

Color rendering is the lamp's ability to accurately show the colors of objects illuminated by that lamp. This attribute is measured in CRI (Color Rendering Index) which peaks at 100. Here is a table of some typical CRI values.

Lamp Type (*)	CRI
Incandescent (**)	100
Cool White Deluxe Fluorescent	90
Metal Halide	70
Warm White Fluorescent	51
Mercury, coated	49
High Pressure Sodium	24
Low Pressure Sodium	-44

* = These are typical CRI values for these lamp types but any one manufacturer's lamp may vary significantly from the values presented here. Please check with your lamp supplier for specific information.

** = The standard lamp used to compute these values is an incandescent lamp so, of course, its CRI would be 100. This is not to imply that all colors are rendered perfectly under incandescent.

EFFICACY

Units: Lumens Per Watt (LPW)

This term is typically used to quantify how efficiently a lamp turns electricity into light. The higher the efficacy, the more efficient the lamp. Here is a table showing the efficacy of some standard lamp types. Please note the wide ranges. Check with your lamp supplier for specific information.

Lamp	Efficacy Lumens/Watt
Edison's First Lamp	1.4
Incandescent	10-40
Halogen	20-45
Fluorescent	35-100
Mercury	50-60
Metal Halide	80-115
High Pressure Sodium	100-140

EFFICIENCY (of a Luminaire)

Previously we defined the ability of a lamp to convert electricity to light as its efficacy. When that lamp is placed in a luminaire (a light fixture) not all of the lamp's light makes it out of the luminaire. The percentage of light from the lamp(s) which is emitted by the luminaire is its efficiency.

COEFFICIENT OF UTILIZATION (CU)

The efficiency of a luminaire says nothing about where the light is going. That is, will the light go where we need it? For example, imagine a luminaire that emits all of its light upward. Then place this luminaire in a room with a black ceiling. The luminaire may have a very high efficiency but very little of its light is reaching our work surface (a desk or the floor). CU provides us with a measure of what percentage of the lamp light from a luminaire actually reaches a horizontal workplane below the luminaire.

As one can imagine, the efficiency of a luminaire remains a constant regardless of what application it is used in. But the CU of a luminaire changes with the dimensions and surface reflectances of the room it is placed in. As the reflectances of the room surfaces decrease so does the CU of the lighting system (as the room surfaces absorb more light, there is less light reaching the work plane).

Less obvious might be how the shape of the room affects the CU. Here we see two rooms that have the same luminaire in each. One can see that as higher angled rays leave the luminaire, they would have a greater chance of hitting a wall (and therefore being partially absorbed) in the tall, thin room to the left. Therefore, for any one luminaire type, the room on the right would have the higher Coefficient of Utilization (assuming the room surface reflectances were the same.)

LUMINAIRE EFFICACY RATING (LER)

Units: Lumens Per Watt (LPW)

Previously we defined efficacy as the lumens per watt for a lamp. Efficiency is the percentage of lamp lumens a luminaire emits. LER is a relatively new metric created by NEMA to describe the efficacy of luminaires. LER is the lumens per watt used by a luminaire. The formula is as follows:

$$LER = \frac{EFF \times TLL \times BF}{Watts}$$

where, EFF is the efficiency of the luminaire

TLL is the total lumens emitted by the lamps in the luminaire

BF is the ballast factor

Watts is the watts input to the luminaire

The following NEMA (National Electric Manufacturers Association) Standards contain minimum LER recommendations for the products listed below.

- LE5 - Fluorescent (commercial & industrial)
- LE5A - Downlights (non-residential - incandescent, fluorescent & HID)
- LE5B - HID Industrials

NEMA created the following groupings of luminaires for comparing LER values:

Fluorescent

FL - Fluorescent Lensed
FS - Fluorescent Strip
FW - Fluorescent Wraparound
FP - Fluorescent Parabolic
FI - Fluorescent Industrial

HID Industrial

HO - HID Open Industrial
HC - HID Closed Industrial

Downlight (non-residential)

DOL - Open/Low Shielding
DBL - Baffle/Low Shielding
DLL - Lensed/Low Shielding
DVL - Louvered/Low Shielding
DOH - Open/High Shielding
DBH - Baffle/High Shielding
DLH - Lensed/High Shielding
DVH - Louvered/High Shielding

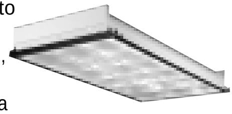
As use of this metric increases, data sheets for most lighting products will include an LER value specified using this format:

LER = FP-62, where: **FP** = Fluorescent Parabolic
62 = 62 lumens/watt

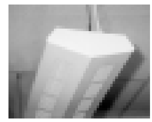
Lighting Products

The following is a short list of the lighting products to be considered when designing a lighting system.

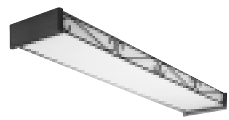
Fluorescent Lighting:



Parabolic Lighting - Recessed and surface mounted products designed to minimize direct glare.
Architectural Lighting - Direct/indirect recessed lighting, linear wallwash, perimeter, and recessed row lighting.
Lensed Troffers - Recessed standard and premium products available in a variety of sizes and lens types.
Indirect and Direct/Indirect Lighting - Pendant mounted products designed for low glare and high comfort in office, library and laboratory applications.



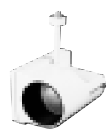
Wall Brackets - Wall-mounted lighting commonly used for stairwells, restrooms, and hospital patient rooms.
Surface Commercials - Products for use under cabinets, wraparounds, and other surface/pendant mounted lighting.
Strips - Various grades of linear fluorescent strip lighting.



Industrials - Reflector industrials with solid top or uplight, damp / wet location luminaires, and cleanroom products.
Decorative - A wide variety decorative styled surface and wall-mounted products including wall sconces.

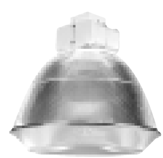
Downlighting and Track:

Downlighting - Specification and light commercial / residential grade products using incandescent, compact fluorescent, HID and low-voltage light sources. A variety of reflector trims are available to accommodate different distribution requirements as well as color and aesthetic preferences. Downlights include open, lensed, wallwash, and accent lighting.



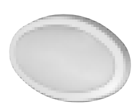
Track lighting - Adjustable tracklighting systems available in a variety of styles and finishes. Tracklighting products utilize various lamps including incandescent, fluorescent, and metal halide. Line voltage and low voltage products are available.

Indoor HID Lighting



High Bays - Open and enclosed products for higher mounting heights, utilizing aluminum reflectors, acrylic or glass refractors.
Low Bays - Enclosed products designed for lower mounting heights, available with aluminum reflectors or acrylic refractors.
General Area - Recessed or surface mounted lensed and louvered area lighting.
Controls - A control system for indoor HID lighting providing multi-level lighting.

Rough Service Lighting

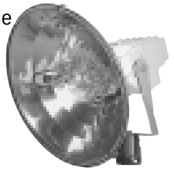


Architectural and general purpose products designed for harsh environments. Rough Service products are designed to use incandescent, fluorescent, compact fluorescent and HID light sources. These products are used in schools, prisons, and public facilities.

Outdoor Lighting

Area Lighting - A wide variety of cutoff and post-top lighting available in various styles, optical control, finishes, and wattages.
Floodlighting - Standard, architectural and high-performance floods available in a variety of sizes and wattages.
Wallpak - Wall-mounted lighting units available in polycarbonate or glass,

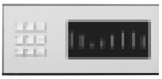
utilizing HID and compact fluorescent sources.
Pathway / Accent Lighting - Decorative bollards and post-top lighting available in various styles, finishes, and wattages.
Landscape Lighting - In-grade, underwater, and floodlighting products designed for architectural outdoor lighting.
Parking Garage Lighting - Lighting products designed specifically for the requirements of parking garages.
Sportslighting - Floodlighting products designed for recreational to professional levels of outdoor sports



Emergency Systems

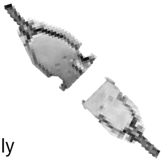
Exit Signs - Architectural, general purpose, heavy duty and rough service exits. Exits utilize incandescent, fluorescent, LED, and self luminous sources. Retrofit exit kits are available to upgrade existing incandescent exits to LED exits.
Emergency Lighting Units - Contemporary to heavy duty products designed to illuminate the path of egress.
Battery Packs - Battery back-up units providing various levels of light for linear and compact fluorescent sources in the event of a power outage.
AC Power Systems - Reliable standby power supply for incandescent, fluorescent or HID lighting systems.

Lighting Control Systems



Dimming - Wallbox dimmers, integrated system photocells, and switches for manual or preset dimming.
Sensing - Ultrasonic and infrared occupancy sensor equipment.
Switching - Control systems integrating switching, scheduling, and energy management functions.

Modular Wiring Systems



Commercial Modular wiring featuring plug-in relocatable components for recessed fluorescent lighting.
Industrial Modular wiring featuring plug-in relocatable components specifically for HID industrial lighting.

Section 3 - Some Technical Stuff

T8 Vs T12 Lamp Technology

As we switch from the T12 lamp (a lamp with a 1.5" diameter) to the T8 (a 1" diameter), as our primary lamp of choice, we are experiencing a greater sustainability on three different fronts.

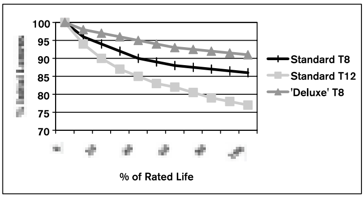
Luminaire Efficiency

Due to the smaller diameter of the T8 tube, the fluorescent luminaire is experiencing a modest gain in luminaire efficiency for two reasons. First the smaller diameter allows the optical designer to have better control of the light. This improvement in control allows the designer to put more of the light on the intended target. Secondly, the smaller diameter means that less light, which is reflecting off the reflector behind the lamp, is being blocked by the lamp.

Lumen Maintenance

The T8 lamps are better able to hold their original rated lumens, i.e. as the lamp approaches its end of life, the T8 is emitting more of its original lumens than the T12. Here we see a chart comparing the lumen maintenance of three lamps:

A standard T12
A standard T8
A deluxe T8



Using these figures, the standard T8 allows for a 9% reduction in the number of luminaires needed while the deluxe T8 allows for a 16% reduction.

Lamp Efficiency

The smaller diameter also allows the lamp manufacturer to take certain technological advantages and increase the efficacy of the lamp. Here is a table comparing T12 with T8.

	Watts	Initial Lumens	CRI	LPW
Old T12	40	3150	70	78.75
T8-40w	40	3400	82	85
T8-32w	32	2950	86	92.19

This shows a 17% improvement of the T8 over the T12 when comparing rated lumens.

The combination of these last two items means that the T8 not only has a higher efficacy when new but then loses those lumens slower over time for a combined improvement of about 35%.

Let’s Talk Ballasts

Why is there a ballast?

The ballast performs two basic tasks:

1. Provides the proper voltage to establish an arc between the two electrodes.
2. Regulates the electric current flowing through the lamp to stabilize light output

In more functional terms, it allows the lamp to start and to run in such a way so as to provide the right amount of light while maximizing the life of the lamp.

What kinds of ballasts are there?

The are three basic kinds of fluorescent ballasts:

1. **Electromagnetic (also called “core & coil” or magnetic)** – these are the oldest of the three and the least efficient.
2. **Hybrid** – these are basically electromagnetic ballasts with a slight twist. They have the same components as the core & coil but with a small bit of electronic circuitry to disconnect the cathode heater windings after a rapid start lamp is ignited. This saves about 3 watts per lamp.
3. **Electronic** – these are the most energy efficient of the three due to their high frequency operation.

Why Electronic Ballasts?

A high percentage of existing installations are still using magnetic ballasts.
The disadvantages of these include:

✓ Heat
✓ Noise
✓ Light output variations
✓ Flicker
✓ Weight
✓ Low Energy efficiency

Advantages of Electronic Ballasts

✓ Energy savings
✓ Reduced weight
✓ No flicker
✓ Reduced heat
✓ Integrates w/lighting management system
✓ No audible noise
✓ Low distortion
✓ Increased reliability

Input Watts Comparison (typical performance)

SYSTEM CONFIGURATION	2 Standard Magnetic Ballasts		2 Energy Efficient Magnetic Ballasts		1 Electronic Ballast	
	Std. Lamps	E/S Lamps	Std. Lamps	E/S Lamps	Std. Lamps	E/S Lamps
3-Lamp Fixture T12 Lamps	147	126	136	115	103	88
3-Lamp Fixture T8 Lamps				102		85
4-Lamp Fixture T12 Lamps	184	156	172	144		
4-Lamp Fixture T8 Lamps				133		115

Now let's discuss some of the individual parameters involved with electronic ballasts.

What about "flicker"?

Electromagnetic ballasts are designed to condition the 60 Hz input voltage to the electrical requirements of the lamps. A magnetic ballast alters the voltage, but not the frequency. Thus, the lamp voltage crosses zero 120 times each second, resulting in 120 Hz light output oscillations. This results in about 30% flicker for standard halophosphor lamps, operated at 60 Hz. The flicker is generally not noticeable but there is evidence that flicker of this magnitude can cause adverse effects, such as eyestrain, headache, and safety hazards when working with high speed machinery.

Most electronic ballasts, on the other hand, use high-frequency operation, which reduces lamp flicker to an essentially unnoticeable level. The flicker percentage of a particular ballast is usually specified by the manufacturer. For a given ballast, the percent flicker will be a function of lamp type and phosphor composition.

What is Total Harmonic Distortion (THD)?

If an electrical device (such as an electronic ballast) connects a non-linear load, the current wave shape will be distorted (no longer a sine wave) and harmonic currents will flow. This can cause electrical problems and should be limited to 20%. Electronic ballasts with less than 10% THD are also available.

What about Power Factor?

Power Factor is a measure of how efficiently a ballast converts the voltage and current supplied from the power source into watts of usable power. Its formula is:

$$\text{Power Factor} = \frac{\text{Input Watts}}{\text{Line Volts} \times \text{Line Amps}}$$

Fluorescent ballasts should always be designated as high power factor (power factor > 90%). Advantages of High Power Factor Ballasts include:

1. Avoids possible penalty charges from the electric utility.
2. Wiring costs are less because normal power factor ballasts result in about twice the line current of high power factor ballasts and may require heavier wire to carry the load.
3. With high power factor ballasts, more fixtures can be installed on each branch circuit.

What is Ballast Factor?

The Ballast Factor is a measurement of a ballast's ability to produce light from fluorescent lamps. It is the ratio of lamp output on a commercial ballast versus its output on an ANSI laboratory standard 60 Hz ballast. A ballast may have different ballast factors for different lamps, e.g., an electronic ballast with standard lamps might have a ballast factor of 95% while the same ballast with energy saving lamps might have a ballast factor of 88%. A ballast factor of 88% means that you will only get 88% of the full lumen output of the lamps and then only when the lighting system is brand new.

And what is Crest Factor?

It is the ratio of peak current to average current. Current that has a high crest factor can cause materials to be eroded from lamp electrodes, prematurely shortening lamp life. Electronic ballast crest factor limits are 1.7 for rapid start lamps and 1.85 for instant start lamps.

What about Ballast Sound?

Ballasts will generate a slight hum and are assigned a sound rating. Please see the following table for suggested rating based on the application.

For Installation In:	Average Ambient Noise Level	Sound Level Rating*
TV or Radio Station; Library; Reception or Reading Room; Church, or School Study Hall	20 – 24 Decibels	A
Residence, Quiet Office, or Night School Classroom	25 – 30 Decibels	B
General Office Area, Commercial Building or Storeroom	31 - 36 Decibels	C
Manufacturing Facility, Retail Store or Noisy Office	37 – 42 Decibels	D
* These sound ratings are based on measurements of Average Ambient noise levels during normal occupancy. Audible ballast hum may appear amplified during quiet periods and at times when the area is under occupied.		

Specialty Ballasts

There are ballasts designed for specific applications or environments, and should be considered as appropriate:

- Dimming Ballasts
- Cold Weather Ballasts
- Sign Ballasts
- Weatherproof Ballasts

Some Sample Savings

Case #1

In a typical commercial setting, a system using four T12 cool white lamps with two standard magnetic ballasts per luminaire was replaced using four T8 lamps and one high performance electronic ballast per luminaire. If we assume that the ballast, 4 lamps and the retrofit labor came to $55 per luminaire and that our system was operational 3,500 hours per year, the system realized the following savings:

Lighting	80 watts/luminaire
A/C	10.5 watts/luminaire
Yearly	317 KwH
CO_2	600 lbs./Year
SO_2	2.8 lbs./Year
NO_x	1.6 lbs./Year

At $0.09/KwH, this saved our user (per luminaire) $28.50/year in energy costs and $3.00/year in maintenance costs resulting in a payback of only 1.8 years.

Case #2

In a Florida school, typical classrooms had 24 4-lamp luminaires using T12 lamps and magnetic ballast. These were replaced with T8 lamps and electronic ballasts. This resulted in an average drop in demand from 0.60kW to 0.45kW for a 25% savings.

Are you in CONTROL of your Lighting?

Lighting controls are used for two basic purposes: energy management and aesthetics. This section provides a brief discussion of the energy management function.

In terms of energy management, there are seven basic scenarios that would imply the use of controls:

1. **Predictable Scheduling** – where activities in a building occur on a routine basis, luminaires can be operated on a fixed schedule (provided that overrides are available).

2. **Unpredictable Scheduling** – irregularly occupied areas, such as copy centers and dressing rooms, can use motion sensors to save energy.
3. **Daylighting** – perimeter areas near the daylighting should be on separate controls to take full advantage of daylight when available.
4. **Brightness Balance** – controls can be used to mitigate offensive differences in brightness such as can occur with daylighting or in tunnel lighting.
5. **Lumen Maintenance** – lighting system output typically decreases with time. Therefore, lighting systems are typically designed to provide sufficient light at the low end of the cycle. Controls can be used to reduce the excess light that is provided at the beginning of the cycle. Such controls then gradually increase power to the lamps, with time, to compensate for their natural losses.
6. **Task Tuning** – frequently lighting systems are designed to provide uniform lighting throughout a space. Task tuning is providing controls so that lighting can be greatest where difficult visual tasks occur and lowest in areas such as aisles and reception areas.
7. **Load Shedding/Demand Reduction** – selective reduction of lighting in less critical areas during peak demand periods can reduce energy bills.

Some questions to ask with regards to any proposed lighting control scheme include:

- ❑ What functions will the processor perform?
- ❑ What output functions are required?
- ❑ What is the size and complexity of the space being controlled?
- ❑ How much change is anticipated for the space and the lighting system?
- ❑ What other systems are proposed for the facility?
- ❑ What is the expertise level of the system operators and maintainers?
- ❑ Is a dedicated processor required?
- ❑ Does the system meet all code and safety requirements?
- ❑ What are the economics of the system?
- ❑ What is the reliability of the system?
- ❑ What are the warranty and service commitments?

Lighting Control Equipment falls into 5 main categories typically:

- ❑ Manual Switching
- ❑ Timing Devices
- ❑ Photosensors
- ❑ Occupancy/Motion Sensors
- ❑ Dimming

Let's discuss some of these in a bit more detail:

Manual Switching

Significant energy savings can be achieved if occupants are willing to switch off unnecessary lights. Some general provisions that allow for this function include:

- ❑ Each separate office should have its own control switch and those with daylighting should have at least two level switching.
- ❑ In large open areas, similar work areas should be grouped together on one circuit.
- ❑ When 1 or 2 lamp luminaires are used, adjacent luminaires should be placed on alternate circuits.
- ❑ For 3 lamp systems, switch the middle lamp on a separate circuit.
- ❑ For 4 lamp systems, the inside pair should be on a different circuit from the outside pair.
- ❑ Task areas with high levels of lighting should be switched on separate switches.
- ❑ Luminaires along windowed walls should be switched on a separate circuit.

Photosensors

A photosensor is an electrical device that measures the current amount of available daylight, and then adjusts the level of electric lighting accordingly. Key to the success of this control technology is the photocell placement and calibration. Photosensor calibration must be easy and accurate.

Another key consideration is the design of the areas to be controlled by photosensors. Each area controlled by a single photosensor should:

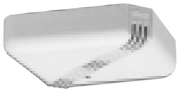
- ❑ Have the same general task activities, illuminance requirements and surrounds.
- ❑ Have the same daylight conditions.
- ❑ Be contiguous, having no high walls or partitions to divide it.

Occupancy/Motion Sensors

As frequent turning off and on can adversely effect lamp life, the challenge in this kind of system is designing the system to trap actual entry/exit patterns, while avoiding false positives (i.e. the lights coming on in an office when someone passes by). To understand the best technology to employ, we need to understand the strengths and weaknesses of each technology

Passive Infrared (PIR) sensors use a dual element sensing device so that when one element senses infrared energy before the other, the sensor assumes occupancy and turned to the occupied state. PIR sensors are strictly line-of-sight devices. They cannot "see" around corners or over partitions and in, general, are best in smaller spaces such as offices, conference rooms, lunchrooms, etc.

Ultrasonic sensors (US) use a quartz crystal oscillator to generate an inaudible signal. The ultrasonic signal is broadcast into a space, bounces off surfaces and returns to the sensor's receiver. Changes in the signal's return time indicate occupancy. Ultrasonic sensors are typically more expensive that PIR but offer greater coverage and have the ability to "see" behind partitions. However, the increased sensitivity means that they are more susceptible to false triggering from such things as HVAC systems, open windows and people walking by open doors to controlled spaces. Ultrasonic sensors are best used in bathrooms, office spaces with partitions, larger open areas, etc.



Microwave sensors are similar to ultrasonic in that a signal is generated and moving objects will cause a shift in the frequency of the return signal. Microwave sensors are primarily limited to the security and alarm industries.

Dual Technology (DT) *sensors* typically utilize both a passive infrared and ultrasonic technology. They offer the combined strengths of both technologies without the weaknesses of each. In addition, the control options are usually configurable by the user. For example, the unit may be set such that both technologies are required to trigger "occupied" and then either to "hold on." Dual technology sensors are especially well suited for classrooms or spaces which are difficult to cover with a single technology.

In general, all occupancy/motion sensors have adjustments for sensitivity, time delay, and coverage patterns. Some even integrate daylight controls to prevent the light from operating when there is sufficient natural daylight.

Sensors can be ceiling, wall or wallbox mounted.

Ceiling-mounted where the first type of motion sensor to be used in lighting applications. They may be used for small or large areas and have few limitations. The typical ceiling mounted system consists of a motion sensor/controller unit and a "switchpack" (transformer plus a relay). The switchpack provides low voltage to the sensor/controller through the transformer and the relay provides switching of the line voltage powering the lights.

Wall-mounted systems are similar to ceiling-mounted and also require a switchpack.

Wallbox systems are single unit and are a direct replacement for normal switches. The transformer and relay are integral to the unit. These units work well for small offices.

Some Sample Savings

A pilot study was done at a federal site in Boulder, CO involving occupancy sensors and desktop dimmers. Offices with just occupancy sensors averaged a 50% reduction in lighting energy used during normal operating hours. Offices that also had manual dimmers averaged a 75% reduction.

Section 4 - At The Application Level

Some Lighting Guidelines

The following guidelines may be used when either lighting new construction or performing a retrofit. As with most ‘guidelines’ there are exceptions to their use. However, such exceptions should be done in a pro-active manner, knowing exactly why an exception is justified.

1. Use Electronic ballasts only (for fluorescent lighting)

- No hybrid or cathode-disconnect ballasts
- No electromagnetic ballasts
- In facilities with a high proportion of non-linear or electronic loads (e.g., hospitals), specify ballasts with low harmonic distortion
- Select *Rapid Start* ballasts for fixtures that are frequently switched or are controlled by occupancy sensors. Select *Instant Start* ballasts for fixtures with long “burn” times.

2. No incandescent lighting

Exceptions might include:

- Dimming applications
- Where used as emergency backup to HID lighting
- Low duty-cycle applications

3. No mercury vapor lighting

A possible exception might be landscape lighting where the mercury might be used for lamp life and color considerations.

4. For low bay/high bay industrial applications:

- For ceiling heights less than 18’-20’, specify high-output 8’ T8 lamps with electronic ballasts
- For ceiling heights greater than 18’-20’, specify HID

5. Outdoor lighting should be controlled by a photocell or some other automatic system

- Photocells should generally be North facing
- Exterior areas not required to have continuous illumination during nighttime hours can benefit from time clocks (e.g. shutting-off fixtures at 1:00 AM).

6. Exit signs should be 2 watts or less under normal conditions

Exits signs should also provide high visibility in a smoke filled environment. LED exit signs are a good choice. Select exit signs which carry the Energy Star logo, indicating that they operate at low energy and meet high visibility requirements.

7. Occupancy sensors recommended for:

- Offices, conference rooms, restrooms and enclosed areas with switched loads greater than 250 watts
- Consider mechanical timer switches for smaller storage areas and closets

8. Consider dual level switching for areas using 3 or 4 lamp luminaires and with:

- Multiple types of work functions within an area
- High density of computer monitors
- Lighting circuits running parallel to a glass wall or other areas with significant ambient light

National Energy Codes may require you to be capable of reducing the connected lighting load by 50% in a fairly uniform pattern.

9. Take advantage of natural daylight:

- For vertical Glazing: luminaires located within a zone that is 15 feet inward and 2 feet to each side of vertical glazing.

- ❑ For horizontal Glazing (skylights): luminaires located within a zone that is the overhead glazing area projected to the ground plus the floor to ceiling height in all directions.
- ❑ Provide these zones with bi-level switching, dimming, light-level control, occupancy sensor, independent switches etc.

10. Tandem Wiring:

- ❑ One-lamp and two-lamp fixtures located in continuous rows or within 10 feet of each other in a recessed ceilings can benefit from tandem wiring. One ballast may be used to power both luminaires which reduces the total number of ballasts to maintain. In addition, a single ballast uses less energy than two ballasts operating the same number of lamps.
- ❑ Tandem wiring is especially useful for providing bi-level switching of 3 or 4 lamp luminaires.

Things To Discuss With Your Lighting Contractor

Lighting represents a critical portion of any building renovation. Both in terms of the energy it uses and in the effect it has on the occupants. A properly designed lighting system generates a space pleasant to work in or visit while providing both the quality and quantity of light necessary to perform the tasks that are expected to be completed. The following are questions that should be asked early in the design process.

- ✓ Who uses the space?
- ✓ How is the space used?
- ✓ How critical is the task being performed?
- ✓ Where is the visual task located?
- ✓ What is the proper quality and quantity of light for the task?
- ✓ Will the space be a pleasant place for users to enter and spend time in?
- ✓ Will the lighting installation be compatible with the architecture?
- ✓ Will the lighting system work with available daylight?
- ✓ What color of light is appropriate? (See Color Temperature and Color Rendering under Lighting Nomenclature.)
- ✓ Will glare or veiling reflections be a problem? (particularly if there are computer monitors in the room)
- ✓ Is the proposed lighting system within budget?
- ✓ Is the lighting system using energy and resources responsibly?
- ✓ Is the lighting system flexible? (Can the system be relocated as the building configuration changes?)
- ✓ How will the lighting system be controlled? (motion sensors, photocells, timers, etc.)
- ✓ What are the applicable codes?
- ✓ Have all safety and emergency issues been attended to?
- ✓ Is the lighting system coordinated:
  - ...with other building systems?
  - ...with the furniture?
- ✓ Is the lighting system easy to maintain?
- ✓ Are replacement parts available?
- ✓ Will the specified products be available on time?
- ✓ Is the designer lighting certified (LC)?

A Bibliography of Helpful Web Sites

Independent Lighting-Related Organizations

www.iesna.org (Illuminating Engineering Society of North America)
www.iald.org (International Association Of Lighting Designers)
www.nlb.org (National Lighting Bureau)
www.nema.org (National Electrical Manufacturers Association)
www.ashrae.org (American Society of Heating, Refrigeration, and Air Conditioning Engineers)
www.qualitylight.com (Light Forum)
http://solstice.crest.org/efficiency/bcap/ (Building Codes Assistance Project-State Energy Codes)
www.plug-in.org (Energy Cost Savings Council)

Government Organizations

www.epa.gov (Environmental Protection Agency)
www.eren.doe.gov/femp (FEMP)
www.climatetreaty.com (Global Climate Change)

Research/Education

www.lrc.rpi.edu (Lighting Research Center)
www.northwestlighting.com (Seattle Lighting Design Lab)

Model Code Organizations

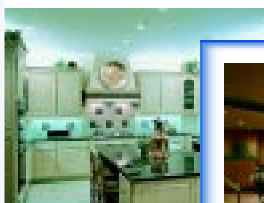
www.bocai.org (Building Officials Code Administrators)
www.icbo.org (International Conference of Building Officials)
www.sbcci.org (Southern Building Code Congress International Inc.)

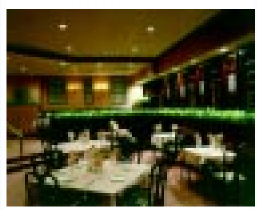
Commercial Organizations

www.lightsearch.com (Inter.Light)
lighting-inc.com/searchman.html (list of lighting manufacturers)
www.llithonia.com (Lithonia Lighting)

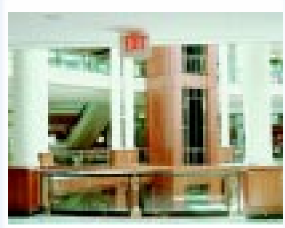
LITHONIA LIGHTING

Lithonia Lighting manufactures commercial and residential downlighting as well as specification-grade and commodity-grade products for industrial and outdoor applications.





Products from Lithonia Emergency Systems, Lithonia Control Systems & Lithonia Reloc Wiring Systems utilize the most advanced technology available.



Lithonia continues to lead the industry with a wide selection of architectural, commercial, industrial and residential fluorescent lighting.

U.S.
Dept. of Energy
Rebuild America S.M.

LITHONIA LIGHTING
BEST VALUE IN LIGHTING

www.lithonia.com/rebuildamerica